Please type a plus sign (+) inside this box [+]

PTO/SB/05 (1/98)

05/29/98

JC587 U.S. PTO

UTILITY PATENT APPLICATION TRANSMITTAL

(Only for nonprovisional applications under 37 CFR § 1.53(b))

Attorney Docket No.	853063.450
First Inventor or Application Identifier	Massimo Mancuso
Title	POST-PROCESSING METHOD FOR REDUCING ARTIFACTS IN BLOCK-CODED DIGITAL IMAGES, AND POST-PROCESSING DEVICE FOR ACTUATING SUCH METHOD
Express Mail Label No.	EM175692149US

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: Box Patent Application, Assistant Commissioner for Patents, Washington, D.C. 20231

1. [X] General Authorization Form & Fee Transmittal (Submit an original and a duplicate for fee processing)
2. [X] Specification [Total Pages] 22
   (preferred arrangement set forth below)
   - Descriptive Title of the Invention
   - Cross References to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to Microfiche Appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings (if filed)
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
3. [X] Drawing(s) (35 USC 113) [Total Sheets] 5
4. Oath or Declaration [Total Pages] 3
   a. [X] Newly executed (original or copy)
   b. [ ] Copy from a prior application (37 CFR 1.63(d)) (for continuation/divisional with Box 17 completed)
      i. [ ] DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b)
5. [ ] Incorporation By Reference (useable if box 4b is checked) The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
6. [ ] Microfiche Computer Program (Appendix)
7. Nucleotide and Amino Acid Sequence Submission (if applicable, all necessary)
   a. [ ] Computer-Readable Copy
   b. [ ] Paper Copy (identical to computer copy)
   c. [ ] Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

8. [X] Assignment Papers (cover sheet & document(s))
9. [ ] 37 CFR 3.73(b) Statement (when there is an assignee) [ ] Power of Attorney
10. [ ] English Translation Document (if applicable)
11. [X] Information Disclosure Statement (IDS)/PTO-1449 [X] Copies of IDS Citations
12. [ ] Preliminary Amendment
13. [X] Return Receipt Postcard
14. [ ] Small Entity Statement(s) [ ] Statement filed in prior application, Status still proper and desired
15. [X] Certified Copy of Priority Document(s) (if foreign priority is claimed)
16. [X] Other: Certificate of Express Mail
    Check

[X] Claims the benefit of European Provisional Application No. 97830264.4 filed May 30, 1997

CORRESPONDENCE ADDRESS

Robert Iannucci
Seed and Berry LLP
6300 Columbia Center
701 Fifth Avenue
Seattle, Washington 98104-7092
(206) 622-4900 *phone*
(206) 682-6031 *fax*

Respectfully submitted,

TYPED or PRINTED NAME Robert Iannucci

REGISTRATION NO. 33,514

SIGNATURE [signature]

Date 5/29/98

PATENT

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Applicants	:	Massimo Mancuso and Rinaldo Poluzzi
Title	:	POST-PROCESSING METHOD FOR REDUCING ARTIFACTS IN BLOCK-CODED DIGITAL IMAGES, AND POST-PROCESSING DEVICE FOR ACTUATING SUCH METHOD
Docket No.	:	853063.450
Date	:	May 30, 1998

Box Patent Application
Assistant Commissioner for Patents
Washington, DC 20231

GENERAL AUTHORIZATION UNDER 37 C.F.R. § 1.136(a)(3) AND FEE TRANSMITTAL

Sir:

With respect to the above-identified application, the Assistant Commissioner is authorized to treat any concurrent or future reply requiring a petition for an extension of time under 37 C.F.R. § 1.136(a)(3) for its timely submission as incorporating a petition therefor for the appropriate length of time. The Assistant Commissioner is also authorized to charge any fees which may be required, or credit any overpayment, to Deposit Account No. 19-1090.

With respect to the above-identified application, the fee is calculated below:

For	Number filed	Number extra		Rate		
Basic Fee						$ **790**
Total Claims	24	4	X	$ 22	=	$ **88**
Independent Claims	3	0	X	$	=	$
Assignment Fee					+	$ **40**
TOTAL FILING FEE						$ **918**

A check in the amount of $918 is enclosed to cover the filing fee.

The Assistant Commissioner is authorized to charge any fees under 37 C.F.R. §§ 1.16 and 1.17 which may be required, or credit any overpayment, to Deposit Account No. 19-1090. A duplicate copy of this request is enclosed.

Respectfully submitted,
Massimo Mancuso and Rinaldo Poluzzi
SEED AND BERRY LLP

Date 5/29/98

Robert Iannucci
Registration No. 33,514

RI:ckt

SEED and BERRY LLP
6300 Columbia Center
701 Fifth Avenue
Seattle, Washington 98104-7092
(206) 622-4900
FAX: (206) 682-6031

WPN\853063\450\General

POST-PROCESSING METHOD FOR REDUCING ARTIFACTS IN BLOCK-CODED DIGITAL IMAGES, AND POST-PROCESSING DEVICE FOR ACTUATING SUCH METHOD

TECHNICAL FIELD

The present invention relates digital image coding. More precisely, the invention relates to a post-processing method for reducing artifacts in block-coded digital images, and to a post-processing device suitable for actuating such a method.

BACKGROUND OF THE INVENTION

With the diffusion of digital communication systems, digital images are more and more used. This has led to the diffusion of still and video cameras with digital acquisition and processing capability.

In order to better exploit storage devices and transmission bandwidth, digital image compression standards have been developed, such as JPEG for still images, and MPEG-1 and MPEG-2 for digital television image sequences.

The above-referred compression standards provide for block-coding based on Discrete Cosine Transform (DCT). A digital image is divided into blocks of pixels, and each block is encoded independently from the others. DCT coefficients for the pixels of each block are evaluated and a quantization matrix is applied to the DCT coefficients to reduce the information to be stored or transmitted. When the image is to be displayed, it must be decoded in advance.

Due to the quantization process, these image compression methods are lossy, *i.e.*, they cause a loss of information in the decoded image with respect to the original image. The decoded image can thus present noticeable degradation, mainly consisting of two kinds of artifacts known in the art under the names of "grid noise" and "staircase noise".

In order to reduce the image degradation, post-processing methods of processing the decoded image have been proposed which allow for attenuating grid noise and staircase noise.

SUMMARY OF THE INVENTION

In view of the state of the art described, it is an object of the present invention to provide a new post-processing method for reducing artifacts in block-coded digital images.

An embodiment of the invention is directed to a post-processing method for reducing artifacts in block-coded digital images. The method includes:

a) dividing an input image into a plurality of image blocks;

b) for each image block, estimating global features of said image block providing information on an average content of image edges along the horizontal and vertical directions of said image block;

c) for each pixel of an image block under examination, estimating local features for said pixel providing information on the content of image edges along the horizontal and vertical directions of an image area around said pixel;

d) modifying the value of said pixel according to both said global features of the image block to which said pixel belongs and said local features of the image area around said pixel.

Another embodiment of the invention is directed to a post-processing device for reducing artifacts in block-coded digital images. The device includes:

- first means supplied with an input image for estimating global features of an image block under examination, said global features providing information on an average content of image edges along the horizontal and vertical directions of said image block;
- second means supplied with said input image for estimating local features for each pixel of the image block under examination, said local features providing information on the content of image edges along the horizontal and vertical directions of an image area around said pixel;

- third means supplied with said global features and said local features for modifying the value of said pixel according to both said global features and said local features.

Features and advantages of the present invention will be made apparent from the following detailed description of an embodiment thereof, illustrated as a non-limiting example in the annexed drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 is a schematic block diagram illustrating a device that implements a method according to the present invention.

Figure 2 shows a digital image divided into image blocks.

Figure 3 shows in detail an image block of the digital image of Figure 2.

Figure 4 shows an array of pixels of the image block of Figure 3.

Figure 5 shows an image sub-block of the image block of Figure 3 used for evaluating global features of the image block.

Figure 6 shows an horizontal processing window used for evaluating local features in the horizontal direction for a generic pixel of the image block.

Figure 7 shows a vertical processing window used for evaluating local features in the vertical direction for said generic pixel.

Figures 8 and 9 shows two membership functions used to perform a fuzzy computation.

Figure 10 is a block diagram of a device according to the present invention.

Figure 11 shows the structure of two blocks of the device of Figure 10.

Figure 12 is a block diagram of two other blocks of the device of Figure 10.

DETAILED DESCRIPTION OF THE INVENTION

With reference to Figure 1, there is shown a block diagram illustrating a device that implements a post-processing method according to the present invention.

An input decoded compressed digital image In is supplied to a Feature Extraction block FE. Block FE provides for analyzing the image to evaluate global and local features thereof. The global and local features, respectively GF and LF, of the image In evaluated by block FE are supplied as inputs to a Fuzzy Process block FUZZY which, according to fuzzy rules, determines parameters FA suitable for determining the kind of filtering to be performed, in accordance to the global and local features GF and FL of the image. The parameters FA calculated by block FUZZY are supplied to a Filter Composition block FC which according to said parameters FA determines the type of filtering to performed out of a set of predefined filters (block FS). Filter parameters FP determined by block FC are then supplied to a Processing block PROC, also supplied directly with the input image In, which performs the filtering of the input image In according to the filter parameters FP to provide a post-processed output image Out.

It appears that the kind of filtering to be performed on the decoded input image In is chosen after an estimation of the global and local features of the decoded input image. For image areas near grid noise and near an edge, a low-pass filtering is performed, to reduce both staircase noise and grid noise. For areas containing fine details (image edges and texture), no filtering is performed. Thus, the method according to the present invention provides for performing a non-linear adaptive filtering on the pixels of the decoded image.

The method outlined above will be now described in detail.

As shown in Figure 2, the input image In is partitioned into image blocks IB, each containing an equal number of pixels. A typical dimension of the blocks is 8*8 pixels (Figure 3), but this is not intended as a limitation, since other block dimensions are suitable.

The image blocks IB of the input image In are scanned line by line starting from the top-left block to the bottom-right one. For each image block IB, the Feature Extraction block FE in Figure 1 determines the global and local features GF and LF.

Global features of the image block IB under examination are determined by applying horizontal and vertical Sobel operators:

$$\text{horizontal Sobel operator (Hsob):} \begin{bmatrix} h11 & h12 & h13 \\ h21 & h22 & h33 \\ h31 & h32 & h33 \end{bmatrix};$$

$$\text{vertical Sobel operator (Vsob)} \quad : \begin{bmatrix} v11 & v12 & v13 \\ v21 & v22 & v23 \\ v31 & v32 & v33 \end{bmatrix}$$

to each pixel belonging to an image sub-block internal to the image block IB. For example, the following Sobel operators:

$$\text{Hsob:} \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix};$$

$$\text{Vsob:} \begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$$

are applied to a 6*6 pixel image sub-block ISB (gray area in Figure 5). As shown in Figure 4, for each pixel Pi of the image sub-block ISB a 3*3 array of neighboring pixels M centered in pixel Pi is considered, and the values of the pixels of said array M are multiplied by the coefficients of the horizontal and vertical Sobel operators, to obtain:

$$\text{Hsob} = (P3+P8+2*P5) - (P1+P6+2*P4),$$

$$\text{Vsob} = (P6+P8+2*P7) - (P1+P3+2*P2),$$

where P1-P4 and P5-P8 are the values of the pixels (gray levels).

As known, horizontal and vertical Sobel operators perform a filtering capable of detecting edges along the horizontal and vertical direction, respectively.

The output values of the horizontal Sobel operators calculated for the pixels of image sub-block ISB are accumulated to obtain an accumulated value Acc(Hsob), and the output values of the vertical Sobel operators calculated for the

pixels of image sub-block ISB are accumulated to obtain an accumulated value Acc(Vsob). Acc(Hsob) gives the high-frequency content in the horizontal direction (vertical edges) of the image block IB. Acc(Vsob) gives the high-frequency content in the vertical direction (horizontal edges) of image block IB. Thus, Acc(Hsob) and Acc(Vsob) respectively provide the degree of "edgeness" of the image block under examination in the vertical and horizontal directions. It is to be noted that in order to evaluate the global features GF of the image block IB under examination, only the pixels belonging to this block are considered (by applying 3*3 Sobel operators to the 6*6 image sub-block ISB, it is not necessary to take into consideration pixels belonging to neighboring image blocks).

Global features GF of the image block under examination can be formed by the accumulated values Acc(Hsob) and Acc(Vsob). Alternatively, the global features GF of the image block can be formed by an average of the accumulated values Acc(Hsob) and Acc(Vsob), to obtain the average number of edges in the horizontal and vertical directions in the image block under examination.

Local features LF of the image block IB are estimated according to the following method. All the pixels of the image block IB under examination are scanned line by line starting from the top-left pixel down to the bottom-right one. To each pixel a horizontal processing window is applied: a prescribed number of pixels respectively preceding and following the pixel under consideration and belonging to the same image line of the pixel under consideration is considered. A suitable horizontal processing window HPW is shown in Figure 6, which is a horizontal 1*5 processing window: for a given pixel, the two preceding pixels Pa, Pb and the two following pixels Pc, Pd belonging to the same line are considered. In Figure 6 there is shown by way of example the horizontal processing window HPW associated to the first pixel Px of the image block. It should be noted that not only the pixels of the image block IB under examination are considered, but also pixels belonging to neighboring image blocks; this is for example the case of the first, second, seventh and eight pixel of each line of pixels of the image block IB under examination.

The horizontal Sobel operator Hsob previously mentioned is applied to each pixel Pa, Pb, Px, Pc, Pd in the horizontal processing window HPW, to obtain five output values HS1-HS5. Values HS1-HS5 provide the local features in the horizontal direction for the pixel under examination Px, *i.e.*, the high-frequency content in the horizontal direction of the image region around the pixel under examination.

Similarly, a vertical processing window is applied to each pixel of the image block IB. The vertical processing window is formed by the pixel under consideration Px, and a prescribed number of pixels belonging to the same column as and preceding and following the pixel under consideration; for example, as shown in Figure 7 the vertical processing window VPW can have dimensions identical to the horizontal processing window HPW (5*1), and thus contains two pixels Pe, Pf preceding pixel Px and two pixels Pg, Ph following pixel Px in the vertical direction.

The vertical Sobel operator Vsob previously mentioned is then applied to each pixel of the vertical processing window VPW to obtain five output values VS1-VS5. Values VS1-VS5 form the local features in the vertical direction for the pixel under examination, *i.e.*, the high-frequency content in the vertical direction of an image region around the pixel under examination.

The global features GF for the image block IB under examination (*i.e.*, the two accumulated values Acc(Hsob) and Acc(Vsob) or, in alternative, the average value of Acc(Hsob) and Acc(Vsob)) and the local features LF for the pixel under examination inside said image block (the ten values HS1-HS5 and VS1-VS5) are then supplied to the Fuzzy Process block FUZZY. The FUZZY block provides for evaluating the degrees of membership of a generic value HSi and Vsi (i=1..5) to two fuzzy sets "Small" and "Big." These degrees of membership can be evaluated by applying to HSi, VSi the membership functions depicted in Figures 8 and 9. In these figures, Th1 and Th2 are values depending on the global features GF of the image block under examination, *i.e.*, on the accumulated values Acc(Hsob) and Acc(Vsob) or on the average of the accumulated values. In the first case, Th1 and Th2 are different for the Hsi and Vsi values; in the second case, Th1 and Th2 are the same for Hsi and Vsi values.

Fuzzy rules having as antecedents the degrees of membership of the output values HSi and VSi to the two fuzzy sets "Small" and "Big" are then evaluated. This means that 32 rules are to be evaluated for both the horizontal and vertical directions. However, all those fuzzy rules having the same consequence are synthesized in one rule only by an else operator. In this way, the system complexity is reduced, and a total of nine rules for each direction have to be evaluated.

The following fuzzy rules are applied to the five values HS1-HS5 associated to the horizontal direction:

1. *If H*S1 *is* Small *and H*S2 *is* Small *and H*S3 *is* Small *and H*S4 *is* Small *and HS5 is* Small, *then* $\alpha 1$ *is* Big;

2. *If H*S1 *is* Small *and H*S2 *is* Small *and H*S3 *is* Small *and H*S4 *is* Small *and HS5 is* Big, *then* $\alpha 2$ *is* Big;

3. *If H*S1 *is* Small *and H*S2 *is* Small *and H*S3 *is* Small *and H*S4 *is* Big *and H*S5 *is* Small, *then* $\alpha 3$ *is* Big;

4. *If H*S1 *is* Small *and H*S2 *is* Small *and H*S3 *is* Small *and H*S4 *is* Big *and H*S5 *is* Big, *then* $\alpha 4$ *is* Big;

5. *If H*S1 *is* Small *and H*S2 *is* Big *and H*S3 *is* Small *and H*S4 *is* Small *and H*S5 *is* Small, *then* $\alpha 5$ *is* Big;

6. *If H*S1 *is* Big *and H*S2 *is* Small *and H*S3 *is* Small *and H*S4 *is* Small *and H*S5 *is* Small, *then* $\alpha 6$ *is* Big;

7. *If H*S1 *is* Big *and H*S2 *is* Small *and H*S3 *is* Small *and H*S4 *is* Small *and H*S5 *is* Big, *then* $\alpha 7$ *is* Big;

8. *If H*S1 *is* Big *and H*S2 *is* Big *and H*S3 *is* Small *and H*S4 *is* Small *and H*S5 *is* Small, *then* $\alpha 8$ *is* Big.

The activation level of each rule depends on the degrees of membership of the pattern of output values HSi of the horizontal Sobel operator applied to the five pixels of the horizontal processing window HPW. The degrees of membership depend in turn on the global features GF of the image block to which the pixel under examination belongs. The activation level of the else (ninth) rule is computed as αelse = (1 - αave), where αave is the average activation degree of fuzzy rules 1 to 8. $\alpha 1$ to

$\alpha8$ and αelse, and a similar set of nine activation degrees for the fuzzy rules applied to values VS1-VS5) form the output FA of the fuzzy process block FUZZY in Figure 1.

Each one of the above-listed rules is associated to a respective set of predefined filter parameters, which are stored as a look-up table in block FS of Figure 1. Suitable predefined filter parameter sets are for example:

Rule 1: (c11=1.0, c12=1.0, c13=1.0, c14=1.0, c15=1.0) if the pixel under examination lies outside the image sub-block ISB, and (c11=0.0, c12=1.0, c13=1.0, c14=1.0, c15=0.0) if the pixel under examination lies inside the image sub-block ISB;

Rule 2: (c21=0.5, c22=1.0, c23=1.0, c24=1.0, c25=0.0);

Rule 3: (c31=0.5, c32=1.0, c33=1.0, c34=0.0, c35=0.0);

Rule 4: (c41=0.5, c42=1.0, c43=1.0, c44=0.0, c45=0.0);

Rule 5: (c51=0.0, c52=0.0, c53=1.0, c54=1.0, c55=0.5);

Rule 6: (c61=0.0, c62=1.0, c63=1.0, c64=1.0, c65=0.5);

Rule 7: (c71=0.0, c72=1.0, c73=1.0, c74=1.0, c75=0.0);

Rule 8: (c81=0.0, c82=0.0, c83=1.0, c84=1.0, c85=0.5);

Else rule: (c91=0.0, c92=0.0, c93=1.0, c94=0.0, c95=0.0).

The parameters FP of the filter to be applied to the five pixels of the horizontal processing window HPW are calculated as a weighted average of the nine filters described above, with weight factors formed by the activation degrees $\alpha1$ to $\alpha8$ and αelse of the respective fuzzy rules.

Assuming that αi is the activation degree of the i-th fuzzy rule (i=1..9), the ninth fuzzy rule being the else fuzzy rule ($\alpha9 = \alpha$else), and cij are the coefficients of the i-th filter (i=1..9, j=1..5), the weight factor applied to the i-th filter, associated to the i-th fuzzy rule is:

$$Fi = \alpha i \bullet cij$$

and the coefficients Hj of the final horizontal filter to be applied to the pixels of the horizontal processing window HPW are given by:

$$Hj = \frac{\sum_{i=1}^{9} \alpha i \bullet cij}{N}$$

where N is a normalization factor.

The horizontally-filtered value <u>Px</u> of the pixel Px under examination (at the center of the horizontal processing window) is then calculated as a weighted average of the values of the pixels Pa, Pb, Px, Pc and Pd belonging to the horizontal processing window HPW, with weight factors formed by the coefficients Hj:

$$\underline{Px} = H1*Pa + H2*Pb + H3*Px + H4*Pc + H5*Pd.$$

Similar calculations are performed for the vertical direction, starting from the output values VS1-VS5 of the vertical Sobel operators applied to the pixels Pe, Pf, Px, Pg and Ph in the vertical processing window VPW. The coefficients Vj (j=1..5) of the filter for the vertical direction are calculated in a way completely similar to that used for determining the coefficients Hj:

$$Vj = \frac{\sum_{i=1}^{9} \beta i \bullet cij}{N}$$

where βi (i=1..9) are the activation degrees of nine fuzzy rules for the vertical direction (similar to those listed above for the horizontal direction) and cij (j=1..5) now are the predefined filter parameters associated to the i-th fuzzy rule for the vertical direction. The coefficients Vj are then applied to the pixels in the vertical processing window VPW to calculate a weighted average of the same. The filtered value of the pixel Px under examination, filtered in both the horizontal and vertical direction, is provided at the output Out of the processing block PROC.

The value of the pixel Px under examination to be multiplied by the vertical filter coefficient V3 can be the value <u>Px</u> obtained after having applied to the pixels in the horizontal processing window HPW the horizontal filter Hj (j=1..5):

$$Out = V1*Pe + V2*Pf + V3*\underline{Px} + V4*Pg + V5*Ph.$$

Alternatively, it is possible to evaluate first the vertically-filtered value $\underline{\underline{Px}}$ of the pixel under examination:

$$\underline{\underline{Px}} = V1*Pe + V2*Pf + V3*Px + V4*Pg + V5*Ph,$$

and then performing the filtering in the horizontal direction applying to this value the respective coefficient H3 of the horizontal filter Hj:

$$Out = H1*Pa + H2*Pb + H3*\underline{\underline{Px}} + H4*Pc + H5*Pd.$$

The sequence is of no importance, the important thing to be underlined being that at the end of the process the value of the pixel under examination is the result of both an horizontal and a vertical filtering.

Figure 10 is a block diagram of a device suitable for actuating the method previously described. The device comprises two main blocks: a global evaluator 1 evaluates the global features GF of the image blocks IB the image to be post-processed is divided in, and a local evaluator 2 evaluates the local features LF of the pixels of the image and performs the filtering according to both the global features and the local features.

It is assumed that the image to be post-processed is scanned line by line in a sequential order. Signal In is a stream of pixels of the input image scanned line by line. The global evaluator is supplied with signal In; signal In also supplies a cascade of two line memories LM1 and LM2 whose outputs supply the global evaluator 1.

Inside the global evaluator 1, signal In and the outputs of line memories LM1 and LM2 supply a first pixel delay module 3 of pixel delays suitable for implementing a 3*3 pixel window which is used to calculate horizontal and vertical Sobel operators for the pixels of the 6*6 image sub-block ISB inside each image block IB. The first pixel delay module 3 supplies a Sobel evaluator 4 which calculates the outputs Hsob and Vsob of the horizontal and vertical Sobel operators for those pixels of the current image line belonging to the 6*6 image sub-blocks ISB of each image block IB. The outputs Hsob and Vsob of the Sobel evaluator 4 are supplied to an accumulator

5 wherein they are accumulated. After eight image lines, *i.e.*, a line of image blocks IB, have been scanned, the accumulated values Acc(Hsob), Acc(Vsob) (or alternatively the average thereof) for each image block IB are stored in a memory 6.

The output of line memory LM2 supplies a cascade of eight further line memories LM3-LM10. The local evaluator 2 is supplied in parallel with the outputs of line memories LM4-LM10. In this way, evaluation of the local features and calculation of the filter parameters starts after the global evaluator 1 has estimated the global features GF for a line of image blocks IB.

Inside the local evaluator 2, a second pixel delay module 7 of pixel delays is supplied with the outputs of line memories LM4-LM10; by means of the line memories LM4-LM10 and the second pixel delay module 7 it is possible to implement the 5*1 vertical processing window VPW. The outputs L4-L10 of the second pixel delay module 7 supply a vertical Sobel evaluator 8 which applies the vertical Sobel operator to each pixel inside the vertical processing window VPW. To avoid the use of further line memories, a parallel approach is preferred providing for calculating five vertical Sobel operators in parallel; the outputs of the five vertical Sobel operators VS1-VS5 are supplied to a vertical fuzzy filter 9, which is also supplied with the outputs L6-L10 of the second pixel delay module 7 and the output MOUT of the memory 6 of the global evaluator 1. MOUT supplies the global features GF of the image block IB currently processed by the local evaluator 2, *i.e.*, the accumulated value Acc(Vsob) or, alternatively, the average of Acc(Vsob) and Acc(Hsob). The vertical fuzzy filter 9 evaluates the degree of membership of values VS1-VS5 to the fuzzy sets "Small" and "Big" taking into account the global features provided by MOUT, evaluates the activation levels of the nine fuzzy rules for the vertical direction, calculates the coefficients Vj (j=1..5) of the vertical filter and applies the vertical filter coefficients Vj to the five pixels Pe, Pf, Px, Pg, Ph in the vertical processing window VPW, to calculate the vertically-filtered value Px of the pixel in the middle of the vertical processing window. The output of the vertical fuzzy filter 9 forms the vertically-filtered value Pd of pixel Pd in the horizontal processing window HPW shown in Figure 6 and supplies directly a horizontal fuzzy filter 10. The output Pd of the vertical fuzzy filter 9 also

supplies a cascade of four pixel delays D whose outputs respectively form the vertically-filtered values $\underline{\underline{Pc}}$, $\underline{\underline{Px}}$, $\underline{\underline{Pb}}$, $\underline{\underline{Pa}}$ of the pixels Pc, Px, Pb, Pa in the horizontal processing window HPW and supply the horizontal fuzzy filter 10.

In parallel to the operation of the vertical Sobel evaluator 8 and the vertical fuzzy filter 9, the outputs L7-L9 of the pixel delay module 7 supply a horizontal Sobel evaluator 11 which applies the horizontal Sobel operators to the pixels inside the horizontal processing window HPW. Differently from the vertical sobel operators, only one horizontal sobel operator is calculated at a time. A compensation delay module 12 introduces a delay for compensating the processing delay of the vertical fuzzy filter 9. The output of the compensation delay module 12, forming the output of the horizontal Sobel operator HS5 applied to pixel Pd of the horizontal processing window in Figure 6, supplies the horizontal fuzzy filter 10 and a cascade of four pixel delays D, the outputs thereof forming the values HS4, HS3, HS2 and HS1 and supplying the horizontal fuzzy filter 10. The horizontal fuzzy filter 10, which is also supplied by the output MOUT of the memory 6 in the global evaluator 1 providing the value Acc(Hsob) (or alternatively the average of values Acc(Hsob) and Acc(Vsob)), evaluates the degree of membership of values HS1-HS5 to the fuzzy sets "Small" and "Big" according to the value of the global features GF provided by MOUT, evaluates the activation levels of the nine fuzzy rules described above for the filtering in the horizontal direction, calculates the coefficients Hj of the horizontal filter and applies the parameters Hj to the vertically-filtered values $\underline{\underline{Pa}}$, $\underline{\underline{Pb}}$, $\underline{\underline{Px}}$, $\underline{\underline{Pc}}$, $\underline{\underline{Pd}}$ of the pixels Pa, Pb, Px, Pc, Pd in the horizontal processing window HPW to obtain the horizontally- and vertically-filtered value Out of the pixel Px under examination.

A control circuit CTRL controls the operation of blocks 1, 2 and the line memories LM1-LM10.

Figure 11 shows the structure of the vertical and horizontal Sobel evaluators 8 and 11 of Figure 10. They are composed in a straightforward way by adders as shown in Figure 11.

Figure 12 shows the structure of both the vertical fuzzy filter 9 and the horizontal fuzzy filter 10. X1-X5 are the vertical or, respectively, horizontal Sobel

operator outputs VS1-VS5 and HS1-HS5. X1-X5 are supplied to a fuzzy rule evaluator 13 which evaluates the activation degrees $\beta 1$-$\beta 9$ of the nine fuzzy rules for the vertical direction or, respectively, the activation degrees $\alpha 1$-$\alpha 9$ of the nine fuzzy rules for the horizontal direction. The activation degrees evaluated by the fuzzy rule evaluator 13 are supplied to a look-up table of respective predefined filter parameters F1-F9 (forming block FS in Figure 1), and the outputs of the look-up table, *i.e.*, the predefined filter parameters cij multiplied by the activation degree of the respective fuzzy rule, are supplied to a filter composition module 14 which calculates the coefficients V1-V5 or, respectively, H1-H5, of the vertical or, respectively, horizontal filter. Said coefficients are then supplied to a processing module 15 which is also supplied with the pixel values PXS (L6-L10 or, respectively, Pa, Pb, Px, Pc, Pd in Figure 10). The processing module 15 applies the filter coefficients to the pixel values to obtain the filtered value of the pixel under examination Px.

It will be appreciated that the structures shown in Figures 1 and 10-12 could be implemented in software on a typical general purpose computer or could be implemented using hardware elements specifically designed for the tasks discussed herein.

From the foregoing it will be appreciated that, although specific embodiments of the invention have been described herein for purposes of illustration, various modifications may be made without deviating from the spirit and scope of the invention. Accordingly, the invention is not limited except as by the appended claims.

CLAIMS

1. A post-processing method for reducing artifacts in block-coded digital images, the method comprising:

a) dividing an input image into a plurality of image blocks;

b) for each image block, estimating global features of said image block by providing information on an average content of image edges along horizontal and vertical directions of said image block;

c) for each pixel of an image block under examination, estimating local features for said pixel by providing information on content of image edges along horizontal and vertical directions of an image area near said pixel; and

d) modifying a value of said pixel according to both said global features of the image block to which said pixel belongs and said local features of the image area near said pixel.

2. The method according to claim 1 wherein the modifying step includes:

d1) defining a set of predefined local features;

d2) determining degrees of coincidence of said local features of the image area near said pixel with each predefined local features of said set, said degrees of coincidence depending on said global features of the image block to which said pixel belongs;

d3) making the value of said pixel equal to a weighted average of the value of said pixel and of the values of neighboring pixels, with weight factors depending on said degrees of coincidence of said local features with each of said predefined local features.

3. The method according to claim 2, said step of determining the degrees of coincidence in step d2) includes performing a fuzzy calculation.

4. The method according to claim 3 wherein each of said predefined local features is associated with a respective group of predefined weight factors, and each of said weight factors is calculated as a weighted average of corresponding predefined weight factors

of said groups with weight coefficients depending on said degrees of coincidence of said local features with each of said predefined local features.

5. The method according to claim 4 wherein said step of estimating global features of the image block under examination provides for applying horizontal and vertical Sobel operators to pixels belonging to an image sub-block internal to said image block under examination.

6. The method according to claim 5 wherein said step of estimating global features of the image block under examination provides for adding outputs of the horizontal Sobel operators applied to each pixel of said image sub-block to obtain an accumulated output of horizontal Sobel operators, and adding outputs of the vertical Sobel operators applied to each pixel of said image sub-block to obtain an accumulated output of vertical Sobel operators.

7. The method according to claim 6 wherein said global features of the image block under examination are formed by said accumulated outputs of the horizontal and vertical Sobel operators.

8. The method according to claim 6 wherein said global features of the image block under examination are formed by an average of said accumulated outputs of the horizontal and vertical Sobel operators.

9. The method according to claim 6 wherein said step of estimating local features for a pixel of the image block under examination includes:

c1) considering a horizontal processing window containing the pixel under examination and neighboring pixels belonging to a same image line as the pixel and preceding and following the pixel;

c2) applying said horizontal Sobel operator to each pixel of the horizontal processing window to obtain a horizontal pattern of horizontal Sobel operator outputs;

c3) considering a vertical processing window containing the pixel under examination and neighboring pixels belonging to a same column of pixels as the pixel and preceding and following the pixel; and

c4) applying said vertical Sobel operator to each pixel of the vertical processing window to obtain a vertical pattern of vertical Sobel operator outputs.

10. The method according to claim 9 wherein said horizontal and vertical processing windows each contains five pixels that are centered at said pixel under examination.

11. The method according to claim 10 wherein step d2) provides for determining degrees of membership of each horizontal Sobel operator output of the horizontal pattern to a first fuzzy set "Small" and to a first fuzzy set "Big", evaluating activation degrees of a first set of fuzzy rules each associated with at least one predefined horizontal pattern of horizontal Sobel operator outputs, determining degrees of membership of each vertical Sobel operator output of the vertical pattern to a second fuzzy set "Small" and to a second fuzzy set "Big" and evaluating activation degrees of a second set of fuzzy rules each associated with at least one predefined vertical pattern of vertical Sobel operator outputs.

12. The method according to claim 11 wherein said step of determining degrees of membership of the horizontal Sobel operator outputs of the horizontal pattern to said first fuzzy sets "Small" and "Big" provides for determining a first and a second membership functions depending on said global features, and said determining degrees of membership of the vertical Sobel operator outputs of the vertical pattern to said second fuzzy sets "Small" and "Big" provides for determining a third and fourth membership functions depending on said global features.

13. The method according to claim 12 wherein said groups of predefined weight factors comprise groups of predefined horizontal weight factors and groups of predefined vertical weight factors, each fuzzy rule of said first set being associated with a

respective one of said groups of predefined horizontal weight factors, and each fuzzy rule of said second set being associated with a respective one of said groups of predefined vertical weight factors.

14. The method according to claim 13 wherein said weight factors comprise horizontal weight factors and vertical weight factors, said horizontal weight factors being determined by making a weighted average of the predefined horizontal weight factors with weight coefficients being formed by the activation degrees of the fuzzy rules of the first set, and said vertical weight factors being determined by making a weighted average of the predefined vertical weight factors with weight coefficients formed by the activation degrees of the fuzzy rules of the second set.

15. The method according to claim 14 wherein the value of the pixel under examination is modified by applying the horizontal weight factors to the values of the pixels in the horizontal processing window and applying the vertical weight factors to the values of the pixels in the vertical processing window.

16. A post-processing device for reducing artifacts in block-coded digital images, characterized by comprising:

first means supplied with an input image for estimating global features of an image block under examination, said global features providing information on an average content of image edges along the horizontal and vertical directions of said image block;

second means supplied with said input image for estimating local features for each pixel of the image block under examination, said local features providing information on content of image edges along the horizontal and vertical directions of an image area around said pixel; and

third means supplied with said global features and said local features for modifying a value of said pixel according to both said global features and said local features.

17. The device according to claim 16 wherein said first means comprises means for evaluating horizontal and vertical Sobel operator outputs of horizontal and vertical Sobel operators applied to pixels of an image sub-block internal to said image block under examination, and accumulator means for accumulating the horizontal Sobel operator outputs and the vertical Sobel operator outputs for each pixel of the image sub-block.

18. The device according to claim 17 wherein said second means comprises fourth means for evaluating vertical Sobel operator outputs of vertical Sobel operators applied to said pixel and to vertically-neighboring pixels preceding and following the pixel in the vertical direction, and fifth means for evaluating horizontal Sobel operator outputs of horizontal Sobel operators applied to said pixel and to horizontally-neighboring pixels preceding and following the pixel in the horizontal direction.

19. The device according to claim 18 wherein said third means comprises vertical filter means supplied with said vertical Sobel operator outputs and said global features for calculating a vertically-filtered value of said pixel depending on said global features, said vertical Sobel operator outputs and the values of said vertically-neighboring pixels, and horizontal filter means supplied with said global features, said horizontal Sobel operator outputs and said vertically-filtered value of said pixel for calculating a horizontally-filtered value of said pixel depending on said global features, said horizontal Sobel operator outputs and the vertically-filtered values of said pixel and said horizontally-neighboring pixels.

20. The device according to claim 19 wherein said verticai filter means comprises first fuzzy computation means supplied with said vertical Sobel operator outputs and said global features for evaluating degrees of coincidence of the pattern of vertical Sobel operator outputs with a set of predefined patterns of vertical Sobel operator outputs, said degrees of coincidence depending on said global features, a look-up table of predefined vertical filter coefficients each one associated to at least one respective predefined pattern of vertical Sobel operator outputs, a vertical filter coefficients composition means supplied with

said predefined vertical filter coefficients for generating a set of vertical filter coefficients which are a weighted average of the predefined vertical filter coefficients with weight coefficients formed by said degrees of coincidence, and a vertical filter supplied with said vertical filter coefficients and the values of the pixel and the vertically-neighboring pixels for providing at an output said vertically-filtered value of the pixel.

21. The device according to claim 20 wherein said horizontal filter means comprises second fuzzy computation means supplied with said horizontal Sobel operator outputs and said global features for evaluating degrees of coincidence of the pattern of horizontal Sobel operator outputs with a set of predefined patterns of horizontal Sobel operator outputs, said degrees of coincidence depending on said global features, a look-up table of predefined horizontal filter coefficients each one associated to at least one respective predefined pattern of horizontal Sobel operator outputs, a horizontal filter coefficients composition means supplied with said predefined horizontal filter coefficients for generating a set of horizontal filter coefficients which are a weighted average of the predefined horizontal filter coefficients with weight coefficients formed by said degrees of coincidence, and a horizontal filter supplied with said horizontal filter coefficients and the vertically-filtered values of the pixel and the horizontally-neighboring pixels for providing at an output said horizontally-filtered value of the pixel.

22. A post-processing method for reducing artifacts in a block-coded digital image, the method comprising:

dividing the digital image into a plurality of image blocks;

for each image block, estimating global features of said image block by providing information on content of said image block along horizontal and vertical directions of said image block;

for each pixel of the image block under examination, estimating local features for said pixel by providing information on content of an image area that includes said pixel and adjacent pixels; and

modifying the pixels of the image block under examination according to both said global features of the image block and said local features the pixels of the image block.

23. The method according to claim 22 wherein said step of estimating global features of the image block under examination includes:

applying horizontal and vertical Sobel operators to pixels belonging to an image sub-block of said image block under examination;

adding outputs of the horizontal Sobel operators applied to each pixel of said image sub-block to obtain an accumulated output of horizontal Sobel operators; and

adding outputs of the vertical Sobel operators applied to each pixel of said image sub-block to obtain an accumulated output of vertical Sobel operators.

24. The method according to claim 22 wherein said step of estimating local features for each pixel of the image block under examination includes:

applying said horizontal Sobel operator to each pixel of a horizontal processing window to obtain a horizontal pattern of horizontal Sobel operator outputs, the horizontal processing window containing the pixel under examination and neighboring pixels belonging to a same image line as the pixel and preceding and following the pixel; and

applying said vertical Sobel operator to each pixel of a vertical processing window to obtain a vertical pattern of vertical Sobel operator outputs, the vertical processing window containing the pixel under examination and neighboring pixels belonging to a same column of pixels as the pixel and preceding and following the pixel.

POST-PROCESSING METHOD FOR REDUCING ARTIFACTS IN BLOCK-CODED DIGITAL IMAGES, AND POST-PROCESSING DEVICE FOR ACTUATING SUCH METHOD

ABSTRACT OF THE DISCLOSURE

A post-processing method reduces artifacts in block-coded digital images. The method includes: dividing an input image into a plurality of image blocks; for each image block, estimating global features of said image block providing information on an average content of image edges along the horizontal and vertical directions of said image block; for each pixel of an image block under examination, estimating local features for said pixel providing information on the content of image edges along the horizontal and vertical directions of an image area near said pixel; modifying the value of said pixel according to both said global features of the image block to which said pixel belongs and said local features of the image area near said pixel.

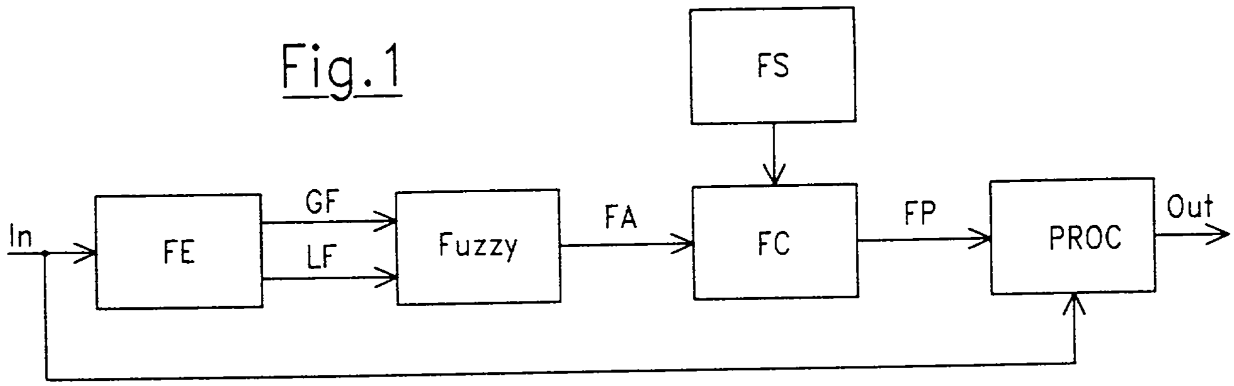


Fig.1

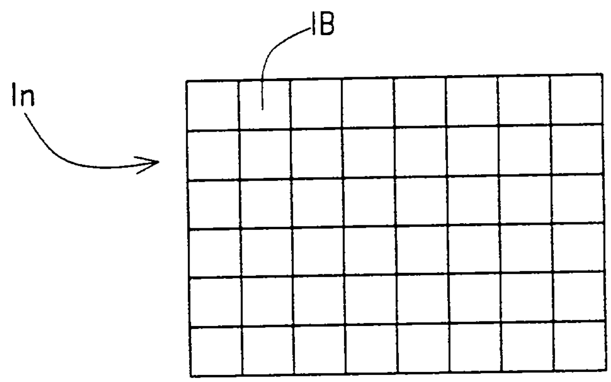


Fig.2

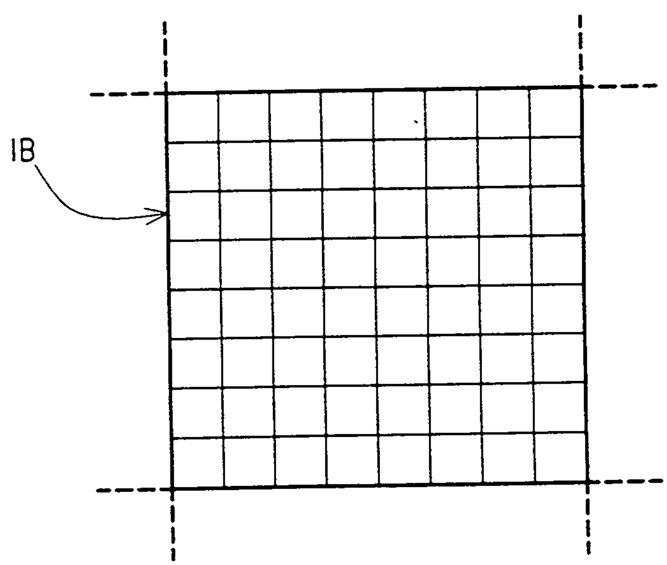


Fig.3

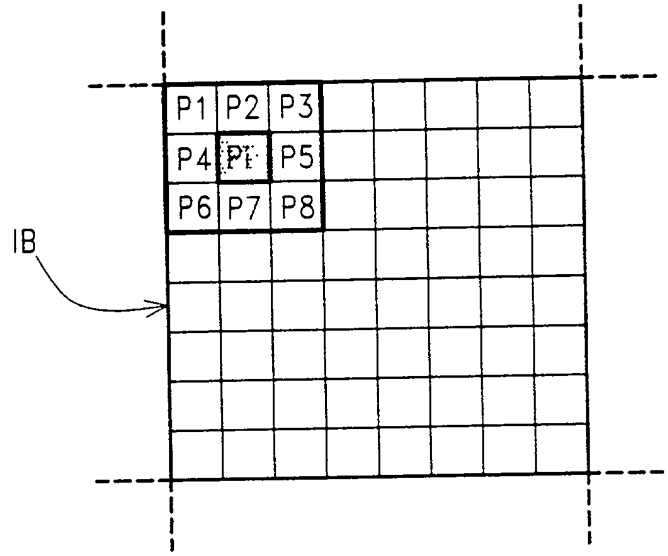


Fig.4

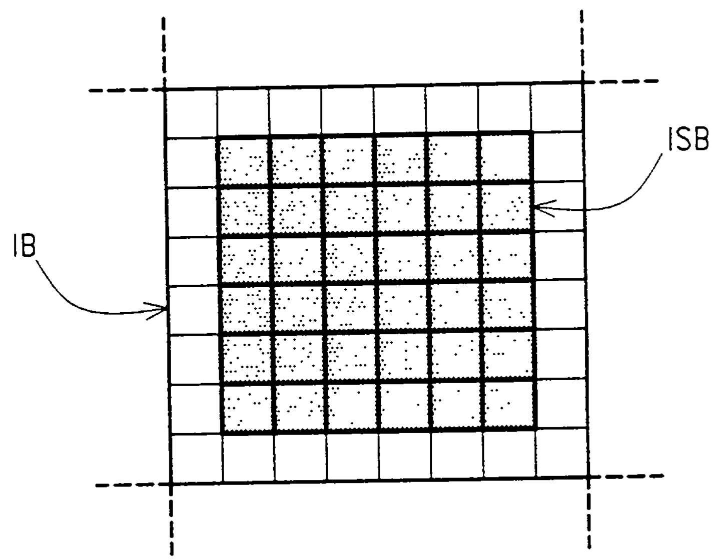


Fig.5

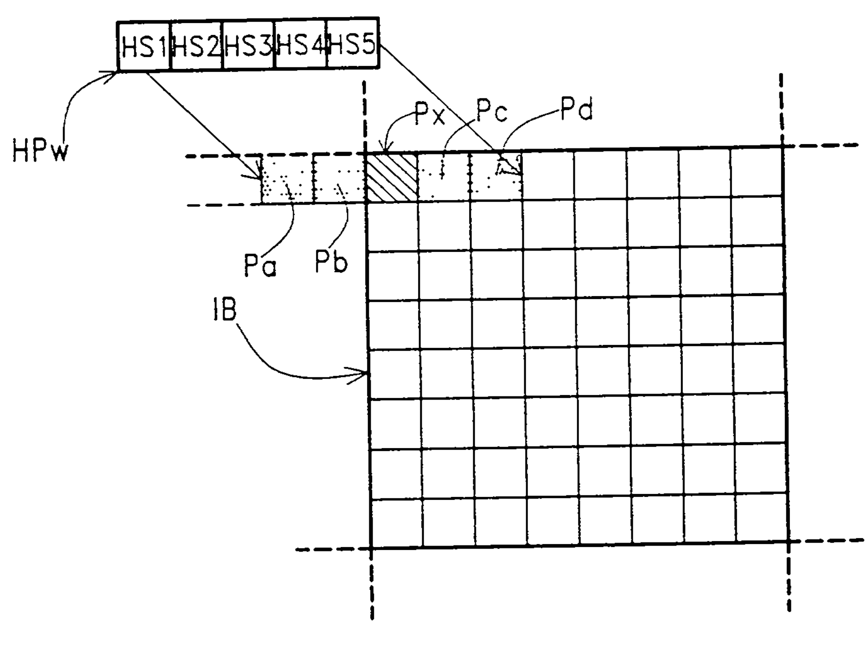


Fig.6

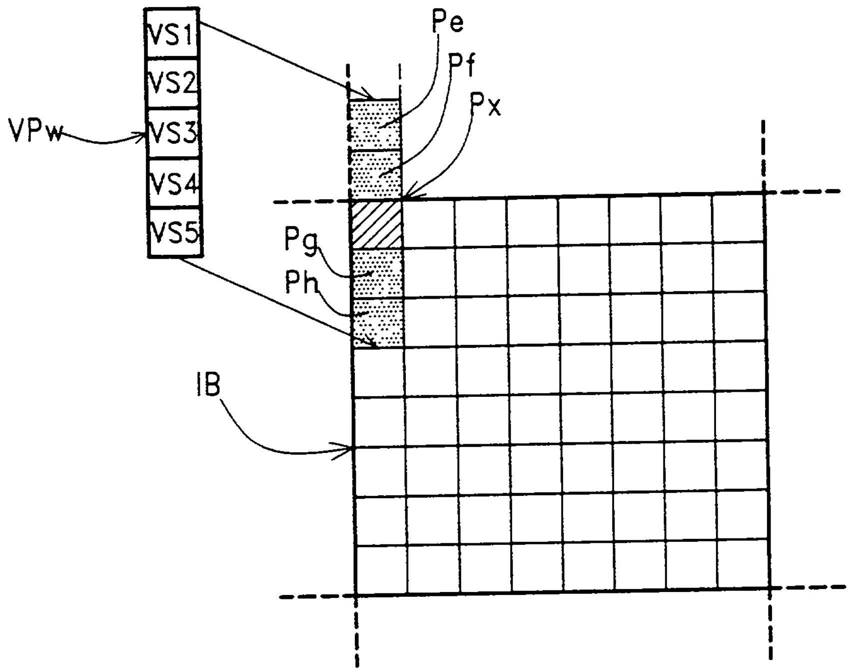


Fig.7

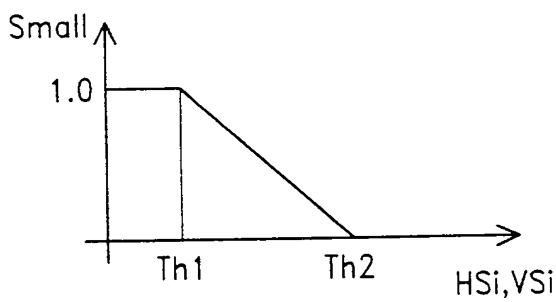


Fig.8

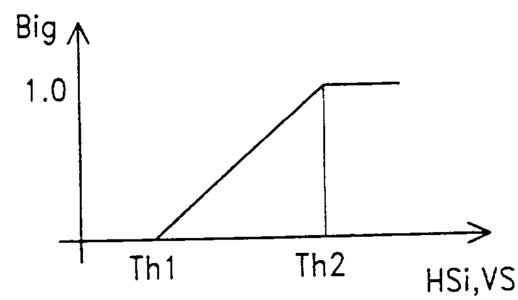


Fig.9

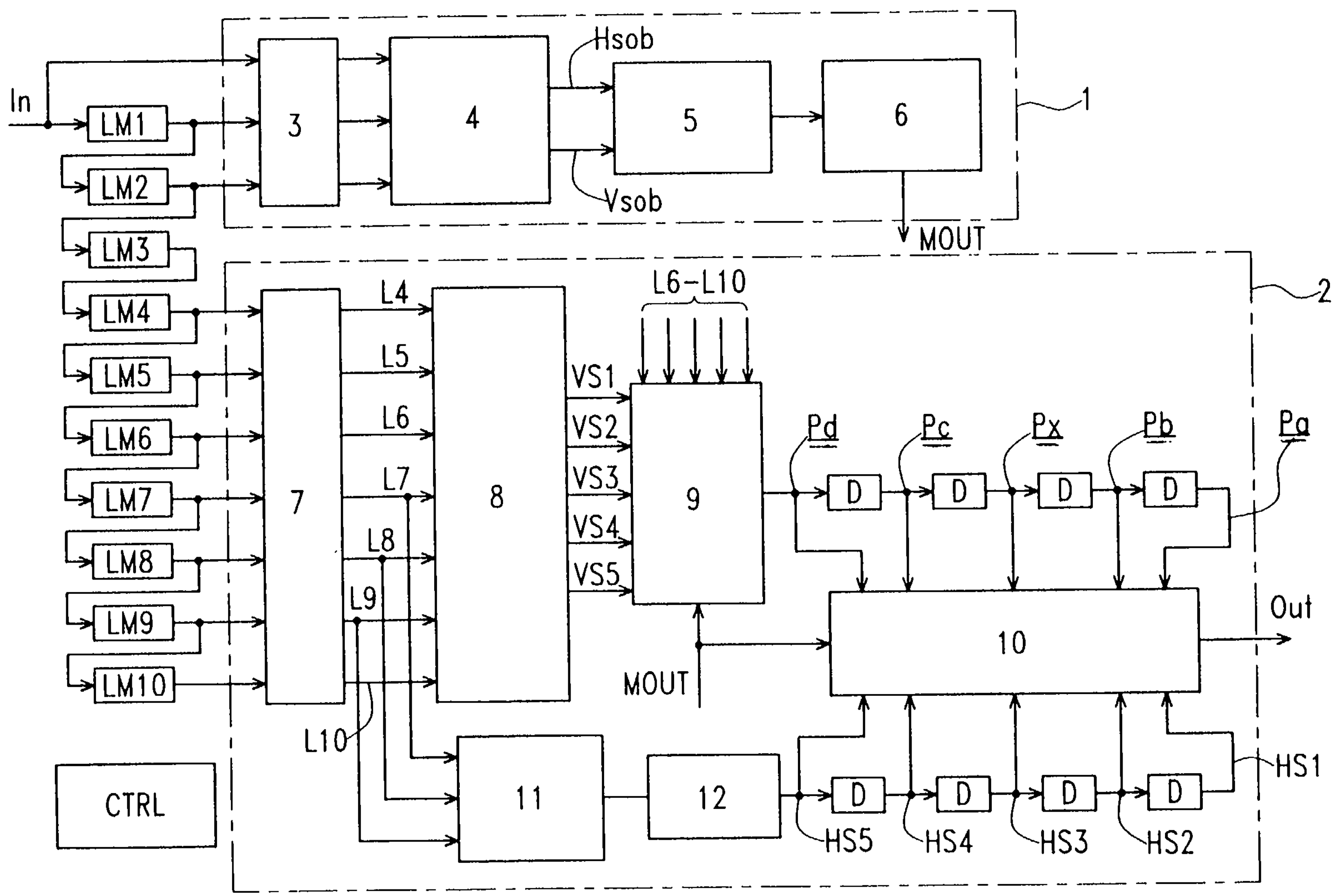
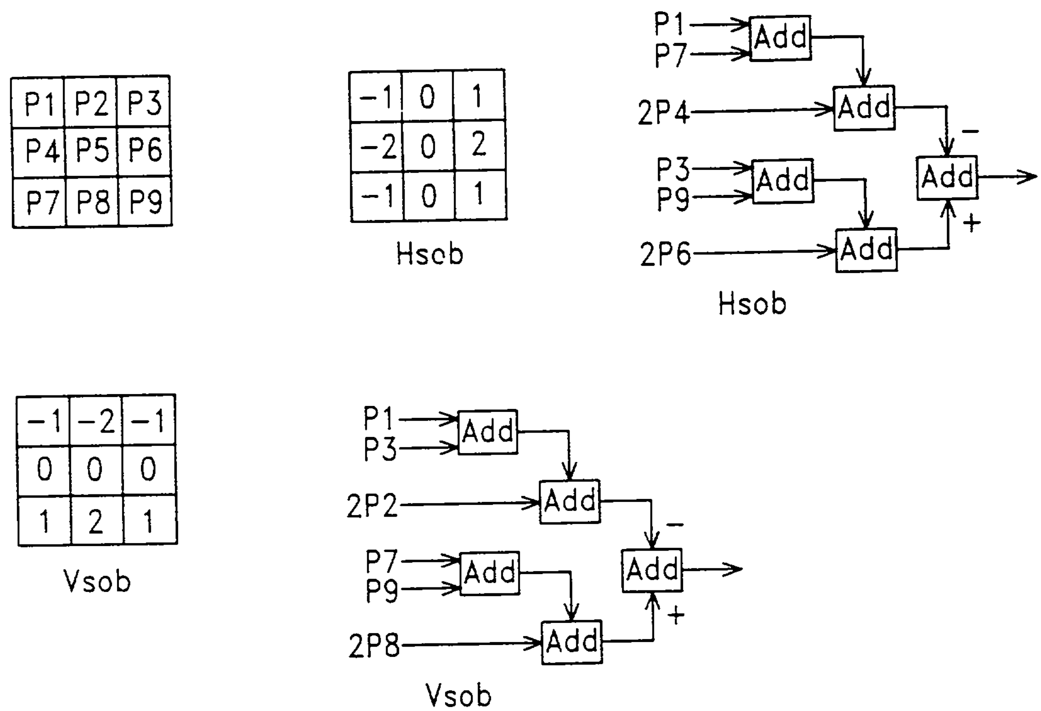
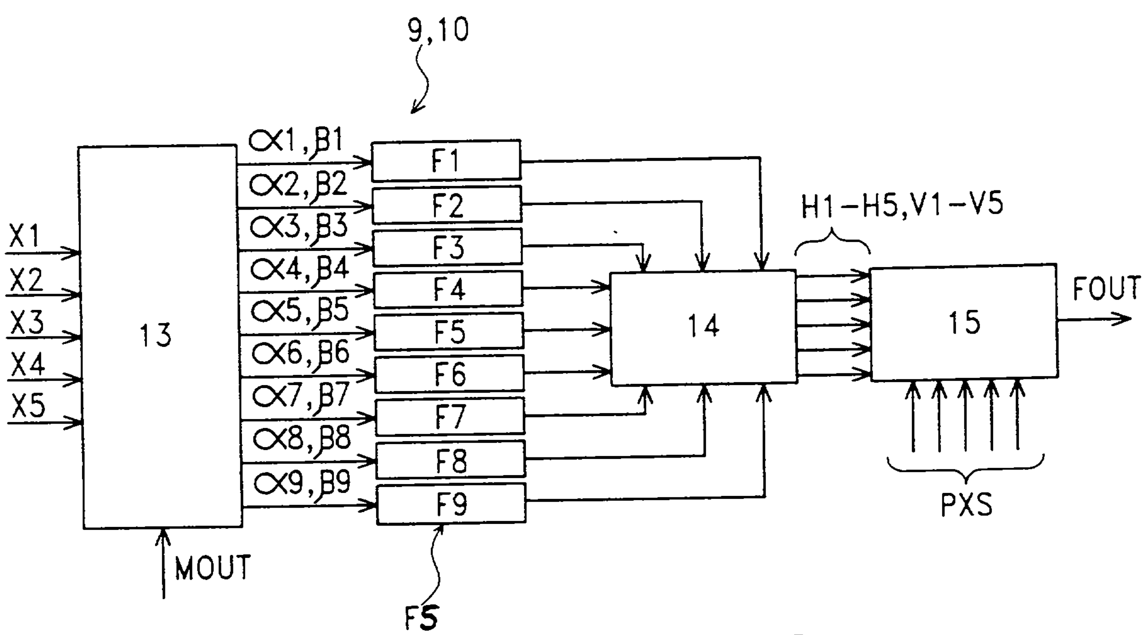

In
LM1
LM2
LM3
LM4
LM5
LM6
LM7
LM8
LM9
LM10
CTRL
3
4
Hsob
Vsob
5
6
MOUT
1
2
7
L4
L5
L6
L7
L8
L9
L10
8
VS1
VS2
VS3
VS4
VS5
L6–L10
9
Pd
Pc
Px
Pb
Pa
D
10
Out
MOUT
11
12
HS1
HS2
HS3
HS4
HS5

Fig.10



P1 P2 P3
P4 P5 P6
P7 P8 P9
−1 0 1
−2 0 2
−1 0 1
Hsob
P1
P7
Add
2P4
Add
−
P3
P9
Add
Add
+
2P6
Add
Hsob
−1 −2 −1
0 0 0
1 2 1
Vsob
P1
P3
Add
2P2
Add
−
P7
P9
Add
Add
+
2P8
Add
Vsob

Fig.11



9,10
X1
X2
X3
X4
X5
13
MOUT
α1,β1
α2,β2
α3,β3
α4,β4
α5,β5
α6,β6
α7,β7
α8,β8
α9,β9
F1
F2
F3
F4
F5
F6
F7
F8
F9
F5
14
H1−H5,V1−V5
15
FOUT
PXS

Fig.12

Declaration and Power of Attorney For Patent Application
Modulo di Dichiarazione Per Domanda di Brevetto
Italian Language Declaration

Io, sottoscritto inventore, dichiaro con il presente che:

As a below named inventor, I hereby declare that:

Il mio domicilio, recapito postale e cittadinanza sono quelli indicati in calce accanto al mio nome,

My residence, post office address and citizenship are as stated below next to my name,

Che mi reputo in buona fede essere l'inventore originario, primo e unico (qualora un solo nominativo appaia elencato appresso) o il coinventore (qualora i nominativi siano piu' di uno) primo e originario delli'invenzione da me rivendicata, e per la quale faccio domanda di brevetto. Tale invenzione é chiamata

____

e la sua descrizione é:

(contrassegnare uno dei due)

☐ qui acclusa.

☐ E'stata presentata il __________ as

Come Domanda Numero __________

ed e'stata rettificata il __________.
(se applicabile)

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled

POST-PROCESSING METHOD FOR REDUCING ARTIFACTS IN BLOCK-CODED DIGITAL IMAGES, AND POST-PROCESSING DEVICE FOR ACTUATING SUCH METHOD.

the specification of which

(check one)

☒ is attached hereto.

☐ was filed on __________

as Application No. __________

and was amended on __________.
(if applicable)

Dichiaro inoltre con il presente di aver letto e compreso il contenuto della specificazione sopra indicata, comprese le rivendicazioni, come rettificata da qualsiasi emendamento a cui si sia accennato sopra.

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

Riconosco il mio dovere di rivelare informazioni che costituiscano materiale per l'esame della presente domanda secondo i termini del Titolo 37, Codice dei Regolamenti Federali, Comma 1,56(a).

I acknowledge the duty to disclose information which is material to the examination of this application in accordance with Title 37, Code of Federal Regulations, §1.56(a).

Italiân Language Declaration

Con il presente rivendico i benefici di priorita' per l'estero come stabilito dal Titolo 35, Codice degli Stati Uniti, Comma 119, per qualsiasi domanda di brevetto (o brevetti) straniera o per qualsiasi certificato d' invenzione sotto elencato, ed ho anche elencato qui sotto tutte le domande di brevetto e certificati d'invenzione stranieri aventi una data di presentazione anteriore a quella della domanda per la quale si rivendica la precedenza:

I hereby claim foreign priority benefits under Title 35, United States Code, §119, of any foreign application(s) for patent or inventor's certificate listed below and have also identified below any foreign application for patent or inventor's certificate having a filing date before that of the application on which priority is claimed:

Prior foreign applications
Domande dall'estero precedenti

			Priority claimed Priorita	Rivendicata
97830264.4 (Number) (Numero)	EUROPE (Country) (Paese)	30 May 1997 (Day/Month/Year Filed) (Giorno, Mese de Anno di Presentazione)	☒ Yes Si	☐ No No
(Number) (Numero)	(Country) (Paese)	(Day/Month/Year Filed) (Giorno, Mese de Anno di Presentazione)	☐ Yes Si	☐ No No
(Number) (Numero)	(Country) (Paese)	(Day/Month/Year Filed) (Giorno, Mese de Anno di Presentazione)	☐ Yes Si	☐ No No

Con il presente rivendico il beneficio previsto dal Titolo 35, Codice degli Stati Uniti, Comma 120, per qualsiasi domanda (o domande) de brevetto sotto indicata, ed entro i limiti nei quali il materiale indicato in ciascuna delle domande di brevetto non e'stato rivelato nella precedente domanda di brevetto americana nel modo previsto dal primo paragrafo del titolo 35, Codice degli Stati Uniti, Comma 112, riconosco il mio dovere di rivelare il materiale d'informazione, cosi' come viene definito nel Titolo 37, Codice dei Regolamenti Federali, Comma 1,56(a), che possa essere venuto ad aggiungersi nel periodo intercorso tra la data di presentazione della domanda precedente e la data nazionale o internazionale PCT di presentazione di questa domanda:

I hereby claim the benefit under Title 35, United States Code, §120, of any United States application(s) listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States application in the manner provided by the first paragraph of Title 35, United States Code, §112, I acknowledge the duty to disclose material information as defined in Title 37, Code of Federal Regulations, §1.56(a), which occurred between the filing date of the prior application and the national or PCT international filing date of this application:

(Application Serial No.) (Numero di serie della Domanda di Brevetto)	(Filing Date) (Data di presentazione)	(Stato Giuridico) (Brevetto, In attesa di Brevetto, Abbandonato)	(Status) (patented, pending, abandoned)
(Application Serial No.) (Numero di serie della Domanda di Brevetto)	(Filing Date) (Data di presentazione)	(Stato Giuridico) (Brevettato, In attesa di Brevetto, Abbandonato)	(Status) (patented, pending, abandoned)

Dichiaro inoltre con il presente che tutte le informazioni da me fornite sono in fede mia vere, e che tutte le affermazioni da me fatte sono in fede mia vere; dichiaro inoltre che quando ho fatto queste affermazioni ero al corrente del fatto che false dichiarazioni fatte intenzionalmente sono punibili con multa o incarcerazione, o ambedue, secondo quanto stabilito dalla sezione 1001 del Titolo 18 del Codice degli Stati Uniti, e che tali informazioni intenzionalmente false possono mettere a repentaglio la validita' della domanda o brevetto rilasciata in base ad esse.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Italian Language Declaration

PROCURA: Io, sottoscritto inventore, nomino con la presente il seguente Procuratore (o Procuratori) o Agente (Agenti) che s'incarica di perseguire questa pratica e di portare a termine tutte le operazioni necessarie all'Ufficio Brevetti e all'Ufficio Marchi di Fabbrica pertinenti a questa practica. (Elencare il Nome e il Numero di Matricola):

POWER OF ATTORNEY: As a named inventor, I hereby appoint the following attorney(s) and/or agent(s) to prosecute this application and transact all business in the Patent and Trademark Office connected therewith (*list name and registration number*)

Richard W. Seed, Reg. No. 16,557
Robert J. Baynham, Reg. No. 22,846
Edward W. Bulchis, Reg. No. 26,847
George C. Rondeau, Jr., Reg. No. 28,893
David H. Deits, Reg. No. 28,066
William O. Ferron, Jr., Reg. No. 30,633
Paul T. Meiklejohn, Reg. No. 26,569
David J. Maki, Reg. No. 31,392
Richard G. Sharkey, Reg. No. 32,629
David V. Carlson, Reg. No. 31,153
Maurice J. Pirio, Reg. No. 33,273
Karl R. Hermanns, Reg. No. 33,507
David D. McMasters, Reg. No. 33,963
Kevin J. Canning, Reg. No. 35,470
Robert Iannucci, Reg. No. 33,514
Joshua King, Reg. No. 35,570
Michael J. Donohue, Reg. No. 35,859
Lorraine Linford, Reg. No. 35,939
Christopher J. Daley-Watson, Reg. No. 34,807
Steven D. Lawrenz, Reg. No. 37,376
Robert G. Woolston, Reg. No. 37,263
Clarence T. Tegreene, Reg. No. 37,951
Ellen M. Bierman, Reg. No. 38,079
Bryan A. Santarelli, Reg. No. 37,560
Michael L. Kiklis, Reg. No. 38,939
Carol Nottenburg, Reg. No. 39,317
Craig S. Jepson, Reg. No. 33,517
Paul T. Parker, Reg. No. 38,264
John C. Stewart, Reg. No. 40,188
Robert W. Bergstrom, Reg No. 39,906
Harry K. Ahn, Reg. No. 40,243
David W. Parker, Reg. No. 37,414
Robert E. Mates, Reg. No. 35,271
Lisa K. Jorgenson, Reg. No. 34,845
Irena Lager, Reg. No. 39,260
Theodore E. Galanthay, Reg. No. 24,122

Recapito per la Corrispondenza:	Send Correspondence to: Robert IANNUCCI Seed and Berry LLP 6300 Columbia Center 701 Fifth Avenue Seattle, Washington 98104
Telefonare a: *(Nome e Numero)*	Direct Telephone Calls to: (*name and telephone number*) Robert IANNUCCI (206) 622-4900

Nome Completo dell'inventore primo e unico	Full name of sole or first inventor Massimo MANCUSO
Firma dell'inventore Data	Inventor's signature Massimo Mancuso Date 14 May 1998
Residenza	Residence MONZA (Milano) - Italy
Cittadinanza	Citizenship Italian
Recapito o Casella Postale	Post Office Address Via Oriani, 19 20052 MONZA (Milano) - Italy
Nome completo del secondo cointentore se applicabile	Full name of second joint inventor, if any Rinaldo POLUZZI
Firma del secondo inventore Rinaldo Poluzzi Data	Second Inventor's signature Rinaldo Poluzzi Date 14 May 1998
Residenza	Residence MILANO - Italy
Cittadinanza	Citizenship Italian
Recapito o Casella Postale	Post Office Address Piazza Istria, 2 20125 MILANO - Italy

(Si prega di fornire stesse informazioni e firme di eventuali terzi e piu' coinventori.)

(Supply similar information and signature for third and subsequent joint inventors.)